Exam Date & Time: 01-Dec-2022 (02:00 PM - 05:00 PM)

MANIPAL ACADEMY OF HIGHER EDUCATION

V SEMESTER B.TECH END SEMESTER EXAMINATIONS, NOV/DEC 2022

TRANSPORT PHENOMENA [CHE 3154]

Marks: 50 **Duration: 180 mins.**

A

Answer all the questions.

Instructions to Candidates: Answer ALL questions Missing data may be suitably assumed

1) From the following data, determine the type of fluid that characterizes it.

A)

Shear Rate, (1/s)	24	170
Shear Stress (N/m^2)	64	1020

(2)

B) State and compare the various laws of transport equations. (3)

C) Consider a Newtonian fluid at constant density and viscosity is flowing in an annular space between two coaxial cylinders. By performing a momentum balance on a thin shell, derive an expression for (5)

- the velocity profile and
- maximum velocity

2) An oil is flowing in laminar region in a 2 cm diameter at the rate of 30 L/min. The oil viscosity is 400 cP and its density is 990 kg/m^3. Calculate

A) (2)
- The wall stress
- Radial position at which the velocity is equal to average velocity

B) In a 0.6 m diameter duct carrying air the velocity profile was found as, u (m/s) = 0.45 - $5r^2$, where r is the radius in m. Determine the volume flow rate of the air and the mean velocity of flow of air. (3)

C) A Newtonian fluid flows down an inclined (ø = angle of inclination with horizontal axis) plane surface in a steady, fully developed laminar film of thickness 'H'. Obtain the expressions for the fluid velocity profile and maximum velocity using Navier-Stokes (5) equations.

3)

A) Consider a large plane wall of thickness L. The wall surface at x=0 is insulated, while the surface at $x = L = 5\ cm$ *is* maintained at a temperature of T_o = 30 °C. The thermal conductivity of the wall, k is constant (30 W/ m K) and the heat is generated in the wall at a rate $q_c = q_m \left[exp\left(-0.5\,\frac{x}{L}\right)\right]$ W/m^3, wherein q_m = 8 MW/m^3. Assuming steady one-dimensional heat transfer. (4)

- Obtain a relation for the variation of temperature in the wall by solving the differential equation, and
- The temperature of the insulated surface of the wall.

B) Liquefied gases are stored in well-insulated spherical containers vented to the atmosphere. Develop an expression for the steady state heat transfer rate through the walls of such a container, with the radii of the inner and outer walls being r_o and r_1 respectively and the temperatures at the inner and outer walls being T_o and T_1. The thermal conductivity of the insulation varies linearly with the temperature from k_o at T_o to k_1 at T_1. (4)

C) Estimate the rate of evaporation (kg/h) of liquid oxygen from a spherical containers of 6 ft inside diameter covered with a 1-ft thick jacket insulation. The following information is available. (2)

- Temperature at inner surface of insulation: -183 °C
- Temperature at outer surface of insulation: 0 °C
- Boiling point of O_2 : - 183 °C
- Heat of vaporization of O_2: 1636 cal/mol
- Thermal conductivity of insulation at 0 °C : 0.155 W/m K
- Thermal conductivity of insulation at - 183 °C : 0.1245 W/m K

4)

A) Consider the base plate of a 1300 W household iron that has a thickness of 1 cm, base area of 400 cm^2 and thermal conductivity 20 W/m°C. The inner surface of the base plat is subjected to uniform heat flux generated by the resistance heaters inside and the outer surface loses heat to the surroundings at 20 °C by convection. By taking the outside convective heat transfer coefficient as 100 W/m^2 °C, evaluate the temperatures at the inner and the outer surfaces. (2)

B) A heated sphere of diameter D is placed in a large amount of stagnant fluid. Consider the heat conduction in the fluid surrounding the sphere in the absence of convection. The thermal conductivity k of the fluid may be considered constant. The temperature at the sphere surface is T_R and the temperature far away from the sphere is T_a. Set up the differential equation describing the temperature T in the surrounding fluid as a function of r, the distance from the centre of the sphere and determine the temperature profile. (3)

(Boundary conditions: @r=R, $T = T_R$ and @ $r = \infty$, $T = T_a$)

C) Derive an expression for observed reaction rate with pore diffusion for a flat slab catalyst, first order reaction. Also, derive an expression for the effectiveness factor. (5)

5) If Thiele-modulus parameter is given by the following expression,

A)
$$\varphi = \frac{V_p}{S_x}\frac{|-r_A|_{C_{AS}}}{\sqrt{2}}\left\{\int_0^{C_{AS}} D_{Ae}(-r_A)dC_A\right\}^{-1/2}$$
(2)

Derive an expression φ for a flat plate & spherical catalyst, ZERO order reaction.

B) You have a porous spherical catalyst particle used for a first order reaction with a rate constant of 6.32 min^{-1} and an effective diffusivity of 3.5 x 10^{-4} cm^2/min. The concentration of the reactant A at the surface is 100 mM. Determine the concentration (mM) of A between 10 and 1000 micrometer catalyst diameter. (Note: Minimum five concentrations have to be calculated) (3)

C) A gaseous substrate is consumed by a catalyst at a rate, which is nearly independent of the substrate concentration. Assume that the catalyst is a sphere of radius r, and let k and C_0 be the substrate consumption rate per unit volume and the substrate concentration just inside the catalyst, respectively. Derive an expression for the steady-state substrate concentration profile inside the catalyst, C(r), assuming that the consumption rate is spatially uniform. (5)

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